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14. ABSTRACT  Amplification of the chromosome 8p11-12 region has been found in approximately 15% of human breast cancer and is associated with poor prognosis. Previous genomic analysis has led us to identify an endoplasmic reticulum (ER) lipid raft-associated 2 (ERLIN2) gene as one of candidate oncogenes within the 8p11-12 amplicon in human breast cancer. ERLIN2 is an ER membrane protein that was recently identified as a novel mediator of ER-associated degradation. In the present study, Gain- and loss-of-function approaches demonstrated that ERLIN2 is a novel oncogenic factor that is associated with the ER stress response pathway. We found that ERLIN2 likely facilitates the adaptation of breast epithelial cells to ER stress by supporting cell growth and protecting the cancer cells from ER stress-induced cell death. Thus, ERLIN2 may confer human breast cancer cells a selective growth advantage by promoting a cytoprotective response to various cellular stresses associated with oncogenesis.					
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## Introduction

Breast cancer cells contain a large number of genetic alterations that act in combination to create the malignant phenotype. Oncogenes, such as *Her2*, play important roles in uncontrolled proliferation and survival of breast cancer cells. However, cancer cells must acquire the ability to tolerate a series of oncogenesis-associated cellular stresses such as DNA damage, proteotoxic, mitotic, metabolic and oxidative stresses (1, 2). To date, very little is known about the genomic basis and molecular mechanisms that allow breast cancer cells to tolerate and adapt to these stresses. Amplification of chromosome 8p11-12 occurs in approximately 15% of human breast cancer (HBC). This region of amplification is significantly associated with disease-specific survival and distant recurrence in breast cancer patients (3-6). Previous work in our laboratory, together with others, have identified an *endoplasmic reticulum (ER) lipid raft-associated 2 (ERLIN2*, also known as *SPFH2*, *C8ORF2*) gene as one of several candidate oncogenes within the 8p11-12 amplicon based on statistical analysis of copy number increase and over expression (3, 4, 7). Yet, the transforming roles of ERLIN2 and molecular mechanisms by which ERLIN2 coordinates ER pathways in breast cancer have not been elucidated. In this research project, we hypothesized that *ERLIN2* plays an important role in the maintenance of malignancy and therapy-resistance through modulation of ERAD signaling in aggressive forms of human breast cancer. Accordingly, we propose that ERLIN2 represents a novel class of oncogenic factors and that targeting ERLIN2 may reduce the therapy resistance of aggressive breast cancers and thus improve the effectiveness of conventional anti-cancer drugs.

## Body

### 1. Specific Aims

This project consists of 3 specific aims:

Aim 1: To investigate the role of ERLIN2 in the maintenance of stress- and apoptosis-resistant phenotypes of aggressive breast cancer cells.

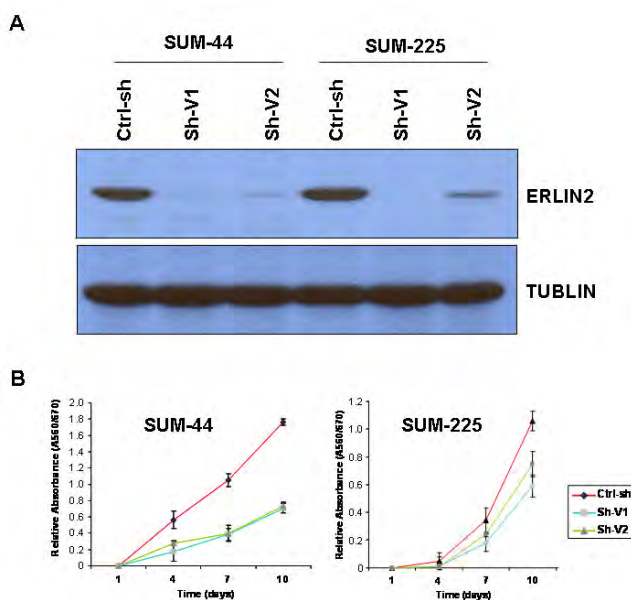
Aim 2: To elucidate the molecular mechanism by which ERLIN2 increases ER protein folding capacity and suppresses ER stress-induced apoptosis in breast cancer cells.

Aim 3: To determine whether inhibition of ERLIN2 activity can enhance the effectiveness of the conventional anti-cancer drugs in aggressive breast cancers.

### 2. Studies and Results

**Task 1 (Dr. Zeng-Quan Yang). To investigate the role of endogenous ERLIN2 up-regulation in the maintenance of stress- and apoptosis-resistant phenotypes of aggressive breast cancer cells. Month 1-16**

To investigate the pathophysiological function of endogenous ERLIN2 in breast cancer cells in which the *ERLIN2* gene is amplified, we stably silenced the *ERLIN2* gene in ERLIN2-amplified SUM-44 and SUM-225 cells using the lentiviral-based shRNA system. To perform RNAi knockdown experiments, we utilized pGIPZ-ERLIN2 shRNA expression constructs in which TurboGFP and shRNA are part of a bicistronic transcript allowing for the visual marking of the shRNA-expressing stable cells. Semi-quantitative RT-PCR and Western blot analysis indicated that expression levels of ERLIN2 mRNA and protein were markedly reduced in the stable ERLIN2-shRNA-transduced SUM-44 and SUM-225 cell lines, compared to the control cell lines that were infected with a non-silencing shRNA lentiviral control. Among the two targeted vectors used, the knockdown effect was more striking for ERLIN2-shRNA vector #1, which resulted in a nearly complete loss of ERLIN2 protein expression in SUM-225 cells (Figure 1A). No change of ERLIN1 mRNA and protein levels was detected in ERLIN2-shRNA knockdown cells, thus ruling out the possible off-target effects of ERLIN2-shRNAs. Cell growth and proliferation analyses showed

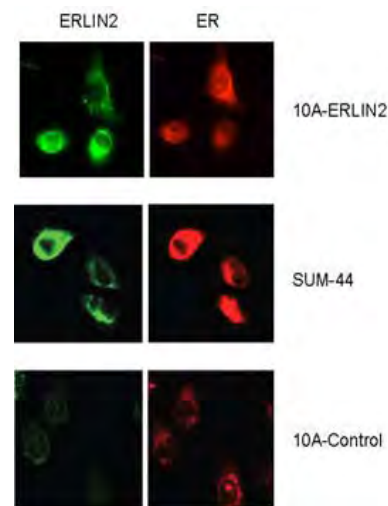


**Figure 1.** shRNA-mediated knockdown of ERLIN2 inhibits growth of breast cancer cells SUM-44 and SUM-225 with ERLIN2 amplification. (A) ERLIN2 expression in SUM-44 and SUM-225 cells was analyzed by western blot after infection with non-silencing control shRNA (Ctrl-sh) or ERLIN2 specific shRNAs (sh-V1 and V2). (B) MTT assay to measure cell viability in SUM-44 and SUM-225 cells after knocked down ERLIN2.

that knockdown of ERLIN2 slowed the proliferation rate of SUM-44 and SUM-225 cells (Figure 1B), but not MCF-10A cells. Knockdown of ERLIN2 in SUM-225 cells also suppressed anchorage-independent growth in soft agar (Data not shown). Taken together, results from knockdown experiments suggested that *ERLIN2* may play an oncogenic role in a subset of human breast cancer. In the next year, we will evaluate the impact of ERLIN2 knockdown or over-expression in ER stress response and apoptotic events in human breast cancer cells.

**Task2 ( Dr. Kezhong Zhang). To elucidate the molecular mechanism by which ERLIN2 regulates ER calcium levels, increases ER capacity, and suppresses ER stress-induced apoptosis in breast cancers. Months 6-20**

To determine the mechanism by which ERLIN2 increase ER protein folding capacity and suppresses stress-induced apoptosis, we first tested the involvement of ERLIN2 in sustaining high levels of ER calcium through mediating degradation of activated IP3 receptor. By determining the ER calcium and cytosolic calcium concentrations in the ERLIN2-knockdown and over-expression cells, we found that calcium signal alteration/ER calcium release is not likely the cause of resistance to apoptosis by ERLIN2 over-expression. Furthermore, we examined the ER expansion in ERLIN2-over-expression cells. The results suggested that ERLIN2 over-expression leads to expansion of ER compartment, a possible mechanism that account for stress- and apoptosis-resistance in ERLIN2-over-expressed cells. For this approach, we utilized confocal fluorescence imaging to visualize the expression and sub-cellular localization of ERLIN2 in ERLIN2-amplified



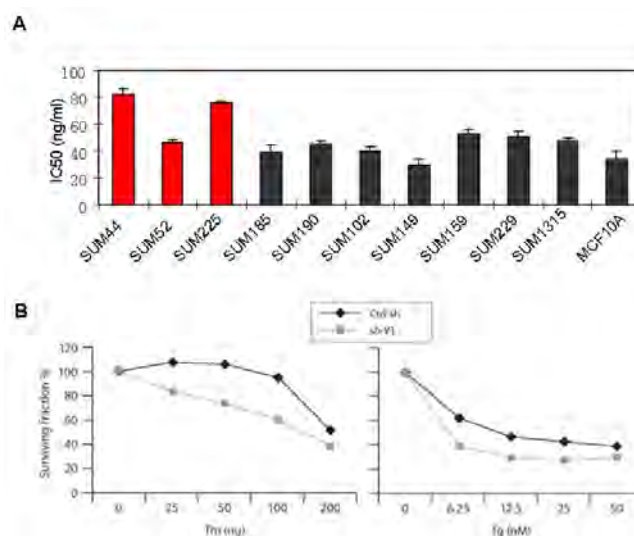
**Figure 2. Confocal analysis of ERLIN2 expression and subcellular localization in MCF10A-ERLIN2, SUM-44 and MCF10A control cells.**

human breast cancer cell lines SUM44 and SUM225. The confocal analysis showed that over-expressed ERLIN2 protein localizes to the ER compartment that is significantly expanded in these breast cancer cells (Figure 2). To further investigate the capacity of ERLIN2 to modulate the structure and abundance of the ER, we exogenously and stably expressed ERLIN2 in MCF10A cells using a lentiviral expression system. Over expression of ERLIN2 mRNA and protein in two ERLIN2-transduced MCF10A pool clones was confirmed with semiquantitative RT-PCR and western blot (Data not shown). Immunofluorescence microscopy demonstrated that enforced expression of ERLIN2 in MCF10A cells triggered ER expansion (Figure 2). These results suggest that increased expression of ERLIN2 would be necessary to equip an enlarged ER compartment for more efficient ER-associated function in a subset of cancer cells. This ER expansion mechanism driven by ERLIN2 over-expression may provide a basis for cancer cell growth and resistance to apoptosis during oncogenesis.

**Task 3 (Dr. Zeng-Quan Yang). To determine whether inhibition of ERLIN2 activity can enhance the effectiveness of conventional anti-cancer drugs in aggressive breast cancers in**

***vitro* and *in vivo* and to evaluate the potential of ERLIN2 as a therapeutic target in aggressive breast cancer. Months 8-24**

In order to detect whether ERLIN2 knockdown can enhance the effectiveness of targeted- and chemotherapeutic drugs *in vitro*, we first examined sensitivities of human breast cancer cell lines with or without the *ERLIN2* gene amplification and over-expression to ER stress-inducing reagents. Figure 3A shows the IC<sub>50</sub> values for the ER stress-inducing reagent Tunicamycin (Tm), in ten breast cancer cell lines as well as nontransformed human mammary epithelial cell line MCF10A. We revealed that SUM-44 and SUM-225 cells with *ERLIN2* amplification exhibited a significant higher in TM IC<sub>50</sub> values ( $P < 0.05$ ), compared to the cell lines without *ERLIN2* amplification. We obtained the similar results with Thapsigargin (Tg) treatment in SUM-44 and SUM-225 cells. Next, we treated the ERLIN2 knocked down SUM-225 cells with Tm and Tg for 72 hours and evaluated their viability using the MTT assay. Knockdown of ERLIN2 resulted in increased sensitivity to Tg or Tm-induced cell death (Figure 3b). Together, these results suggest that over expression of ERLIN2 may facilitate the adaptation of breast epithelial cells to ER stress by supporting cell growth. In the next year, we will investigate whether inhibition of ERLIN2 activity can enhance the effectiveness of anti-cancer drugs by utilizing our established *in vitro* models and in xenograft mouse models.



**Figure 3.** (A) IC<sub>50</sub> values for the Tunicamycin (Tm), in ten breast cancer cell lines as well as nontransformed human mammary epithelial cell line MCF10A (B) Cell viability of ERLIN2 knockdown and control SUM-225 cells was measured with MTT assays after exposure to different concentrations of the Tm or Tg for 72 hours.

## **Key Research Accomplishments**

In the present study, we investigated the transforming properties of newly identified 8p11-12 candidate oncogene ERLIN2 *in vitro*. We found knockdown of ERLIN2 in 8p11-12 amplified human breast cancer cells resulted in profound loss of growth and survival of these cells. Furthermore, ERLIN2 has the ability to protect breast cancer cells from ER stress-induced cell death. We revealed that ER expansion mechanism driven by ERLIN2 amplification and over-expression may provide a basis for cancer cell growth and resistance to apoptosis during oncogenesis.

## **Reportable Outcomes**

### **Manuscript:**

**“ERLIN2 promotes breast cancer cell survival by modulating endoplasmic reticulum stress pathways”** In preparation

### **Abstracts:**

“Endoplasmic reticulum factor ERLIN2 plays an oncogenic role by modulating ER stress response in breast cancer” DOD BCRP Era of Hope Meeting 2011

“Endoplasmic Reticulum Factor ERLIN2 Preserves Oncogenesis by Regulating De novo Lipogenesis” DOD BCRP Era of Hope Meeting 2011

## **Conclusion**

We have made significant progress in the past year in characterizing the endoplasmic reticulum factor ERLIN2 in human breast cancer. We found that ERLIN2 is amplified and over expressed in a subset of human breast cancer cells. Gain- and loss-of-function approaches demonstrated that ERLIN2 is a novel oncogenic factor that is associated with the ER stress response pathway. We show that over expression of ERLIN2 facilitated the adaptation of breast epithelial cells to ER stress by supporting cell growth and protecting the cells from ER stress-induced cell death. Thus, ERLIN2 may confer breast cancer cells a selective growth advantage for by promoting a cytoprotective response to various cellular stresses associated with oncogenesis.



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